

QUALITATIVE DISCUSSION OF ATLANTIC BASIN SEASONAL HURRICANE ACTIVITY FOR 2012

We are discontinuing our early December quantitative hurricane forecast for the next year and giving a more qualitative discussion of the factors which will determine next year's Atlantic basin hurricane activity. Our early December Atlantic basin seasonal hurricane forecasts of the last 20 years have not shown real-time forecast skill even though the hindcast studies on which they were based had considerable skill. Reasons for this unexpected lack of skill are discussed.

Our first quantitative forecast for 2012 will be issued on Wednesday, April 4.

(as of 7 December 2011)

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This discussion as well as past forecasts and verifications are available via the World Wide Web at <http://hurricane.atmos.colostate.edu>

Emily Wilmsen, Colorado State University Media Representative, (970-491-6432) is available to answer various questions about this discussion

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“It is better to be qualitatively right than quantitatively wrong.” Warren Buffett

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ABSTRACT

We are providing a qualitative discussion of features likely to impact the 2012 Atlantic basin hurricane season rather than a specific numbers forecast. We have suspended issuing quantitative forecasts at this extended-range lead time, since they have not proved skillful over the last 20 years. We attribute the primary reasons for the lack of skill of our early December forecast due to the breakdown of several long-term relationships that worked well in many years of hindcast data, but not in real-time forecasting. We would never have issued a seasonal hurricane forecast that did not show significant skill on many years of hindcast data. In addition, no statistical or dynamical models have shown skill at predicting El Niño – Southern Oscillation (ENSO) at this extended forecast lead time of 9-12 months. This outlook for 2012 will give our assessment of the probability of four potential scenarios for Net Tropical Cyclone (NTC) activity.

We have developed a new way of assessing next year's activity in terms of two primary physical parameters:

1. the strength of the Atlantic thermohaline circulation (THC)
2. the phase of ENSO

We have been in an active era for Atlantic basin tropical cyclones since 1995, and we expect that typical conditions associated with a positive Atlantic Multi-Decadal Oscillation (AMO) and strong thermohaline circulation (THC) to continue. Several forecast models and a qualitative analysis of current conditions in the tropical Pacific indicate that the odds of an El Niño developing this year are somewhat higher than they have been during the past couple of years. In addition, tropical Atlantic sea surface temperatures (SSTs) tend to cool following La Niña events (such as we are currently experiencing), and these will also have to be closely monitored for the upcoming hurricane season. We anticipate that the 2012 Atlantic basin hurricane season will be primarily determined by the strength of the THC/AMO and by the state of ENSO.

We anticipate four possible scenarios with the probability of each as indicated on the next page:

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1. THC circulation becomes unusually strong in 2012 and no El Niño event occurs (resulting in a seasonal average net tropical cyclone (NTC) activity of ~ 180) – **15% chance**.
 2. THC continues in the above-average condition it has been in since 1995 and no El Niño develops (NTC ~ 140) – **45% chance**.
 3. THC continues in above-average condition it has been in since 1995 with the development of a significant El Niño (NTC ~ 75) – **30% chance**.
 4. THC becomes weaker and there is the development of a significant El Niño (NTC ~ 40) – **10% chance**.
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Typically, seasons with the above-listed NTC values have TC activity as follows:

180 NTC – 14-17 named storms, 9-11 hurricanes, 4-5 major hurricanes

140 NTC – 12-15 named storms, 7-9 hurricanes, 3-4 major hurricanes

75 NTC – 8-11 named storms, 3-5 hurricanes, 1-2 major hurricanes

40 NTC – 5-7 named storms, 2-3 hurricanes, 0-1 major hurricanes

Acknowledgment

This year's forecasts are funded by private and personal funds. We are grateful for EarthRisk Technologies' financial and technical assistance in exploring the development of 5-14-day hurricane forecasts. We thank the GeoGraphics Laboratory at Bridgewater State College (MA) for their assistance in developing the United States Landfalling Hurricane Probability Webpage (available online at <http://www.e-transit.org/hurricane>).

The second author gratefully acknowledges the valuable input to his CSU seasonal forecast research project over many years by former graduate students and now colleagues Chris Landsea, John Knaff and Eric Blake. We also thank Professors Paul Mielke and Ken Berry of Colorado State University for much statistical analysis and advice over many years. We thank Bill Thorson for technical advice and assistance.

Change of Atlantic Basin Hurricane Climatology

We are changing our climatology from the 1950-2000 mean to the 1981-2010 median. The primary reason we are doing this is to take into account the increased number of weaker named storms during the latter part of the 20th century and the early part of the 21st century. This is due to the fact that with vastly improved observational capabilities, more weak tropical cyclones are being identified.

While a sixty-year climatology is needed to take into account the full observed Atlantic multi-decadal variability associated with the Atlantic Multi-decadal Oscillation (AMO) or thermohaline circulation (THC), we are using a shorter, thirty-year climatology. We feel this is justified because about half of the years from 1981-2010 were part of an active phase of the AMO (1995-2010) while the other half were part of an inactive phase of the AMO (1981-1994). We are also changing to use the median as opposed to the mean, as the median is more robust to large outlier seasons (such as 2004 and 2005). Table A compares the 1950-2000 mean climatology versus our new 1981-2010 median climatology.

Table A: The 1950-2000 climatological mean (our old climatology baseline) and the 1981-2010 climatological median (our new climatology baseline).

Forecast Parameter	1950-2000 Mean	1981-2010 Median
Named Storms (NS)	9.6	12.0
Named Storm Days (NSD)	49.1	60.1
Hurricanes (H)	5.9	6.5
Hurricane Days (HD)	24.5	21.3
Major Hurricanes (MH)	2.3	2.0
Major Hurricane Days (MHD)	5.0	3.9
Accumulated Cyclone Energy (ACE)	96	92
Net Tropical Cyclone Activity (NTC)	100	103

DEFINITIONS AND ACRONYMS

Accumulated Cyclone Energy (ACE) - A measure of a named storm's potential for wind and storm surge destruction defined as the sum of the square of a named storm's maximum wind speed (in 10^4 knots²) for each 6-hour period of its existence. The 1950-2000 average value of this parameter is 96 for the Atlantic basin.

Atlantic Multi-Decadal Oscillation (AMO) - A mode of natural variability that occurs in the North Atlantic Ocean and evidencing itself in fluctuations in sea surface temperature and sea level pressure fields. The AMO is likely related to fluctuations in the strength of the oceanic thermohaline circulation. Although several definitions of the AMO are currently used in the literature, we define the AMO based on North Atlantic sea surface temperatures from 50-60°N, 10-50°W.

Atlantic Basin - The area including the entire North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico.

El Niño - A 12-18 month period during which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. Moderate or strong El Niño events occur irregularly, about once every 3-7 years on average.

Hurricane (H) - A tropical cyclone with sustained low-level winds of 74 miles per hour (33 ms^{-1} or 64 knots) or greater.

Hurricane Day (HD) - A measure of hurricane activity, one unit of which occurs as four 6-hour periods during which a tropical cyclone is observed or is estimated to have hurricane-force winds.

Madden Julian Oscillation (MJO) - A globally propagating mode of tropical atmospheric intra-seasonal variability. The wave tends to propagate eastward at approximately 5 ms^{-1} , circling the globe in roughly 40-50 days.

Main Development Region (MDR) - An area in the tropical Atlantic where a majority of major hurricanes form, which we define as 10-20°N, 20-70°W.

Major Hurricane (MH) - A hurricane which reaches a sustained low-level wind of at least 111 mph (96 knots or 50 ms^{-1}) at some point in its lifetime. This constitutes a category 3 or higher on the Saffir/Simpson scale.

Major Hurricane Day (MHD) - Four 6-hour periods during which a hurricane has an intensity of Saffir/Simpson category 3 or higher.

Multivariate ENSO Index (MEI) - An index defining ENSO that takes into account tropical Pacific sea surface temperatures, sea level pressures, zonal and meridional winds and cloudiness.

Named Storm (NS) - A hurricane, a tropical storm or a sub-tropical storm.

Named Storm Day (NSD) - As in HD but for four 6-hour periods during which a tropical or sub-tropical cyclone is observed (or is estimated) to have attained tropical storm-force winds.

Net Tropical Cyclone (NTC) Activity - Average seasonal percentage mean of NS, NSD, H, HD, MH, MHD. Gives overall indication of Atlantic basin seasonal hurricane activity. The 1950-2000 average value of this parameter is 100.

Oceanic Niño Index (ONI) - Three-month running mean of SST in the Niño 3.4 region (5°N-5°S, 120°-170°W).

Saffir/Simpson Scale - A measurement scale ranging from 1 to 5 of hurricane wind and ocean surge intensity. One is a weak hurricane; whereas, five is the most intense hurricane.

Southern Oscillation Index (SOI) - A normalized measure of the surface pressure difference between Tahiti and Darwin. Low values typically indicate El Niño conditions.

Sea Surface Temperature - SST

Sea Surface Temperature Anomaly - SSTA

Thermohaline Circulation (THC) - A large-scale circulation in the Atlantic Ocean that is driven by fluctuations in salinity and temperature. When the THC is stronger than normal, the AMO tends to be in its warm (or positive) phase, and more Atlantic hurricanes typically form.

Tropical Cyclone (TC) - A large-scale circular flow occurring within the tropics and subtropics which has its strongest winds at low levels; including hurricanes, tropical storms and other weaker rotating vortices.

Tropical North Atlantic (TNA) index - A measure of sea surface temperatures in the area from 5.5-23.5°N, 15-57.5°W.

Tropical Storm (TS) - A tropical cyclone with maximum sustained winds between 39 mph (18 ms^{-1} or 34 knots) and 73 mph (32 ms^{-1} or 63 knots).

Vertical Wind Shear - The difference in horizontal wind between 200 mb (approximately 40000 feet or 12 km) and 850 mb (approximately 5000 feet or 1.6 km).

$$1 \text{ knot} = 1.15 \text{ miles per hour} = 0.515 \text{ meters per second}$$

1 Introduction

This is the 29th year in which the CSU Tropical Meteorology Project has made forecasts of the upcoming season's Atlantic basin hurricane activity. Our research team has shown that a sizable portion of the year-to-year variability of Atlantic tropical cyclone (TC) activity can be hindcast with skill exceeding climatology. These forecasts are based on a statistical methodology derived from 30-60 years of past data. Qualitative adjustments are added to accommodate additional processes which may not be explicitly represented by our statistical analyses. These evolving forecast techniques are based on a variety of climate-related global and regional predictors previously shown to be related to the forthcoming seasonal Atlantic basin TC activity and landfall probability. We believe that seasonal forecasts must be based on methods that show significant hindcast skill in application to long periods of prior data. It is only through hindcast skill that one can demonstrate that seasonal forecast skill is possible. This is a valid methodology provided that the atmosphere continues to behave in the future as it has in the past.

The best predictors do not necessarily have the best individual correlations with hurricane activity. The best forecast parameters are those that explain the portion of the variance of seasonal hurricane activity that is not associated with the other forecast variables. It is possible for an important hurricane forecast parameter to show little direct relationship to a predictand by itself but to have an important influence when included with a set of 2-3 other predictors.

A direct correlation of a forecast parameter may not be the best measure of the importance of this predictor to the skill of a 2-3 parameter forecast model. This is the nature of the seasonal or climate forecast problem where one is dealing with a very complicated atmospheric-oceanic system that is highly non-linear. There is a maze of changing physical linkages between the many variables. These linkages can undergo unknown changes from weekly to decadal time scales. It is impossible to understand how all these processes interact with each other. No one can completely understand the full complexity of the atmosphere-ocean system. But, it is still possible to develop a reliable statistical forecast scheme which incorporates a number of the climate system's non-linear interactions. Any seasonal or climate forecast scheme must show significant hindcast skill before it is used in real-time forecasts.

2 Previous Extended-Range Early December Statistical Forecasts

Our seasonal hurricane forecast schemes issued in early June and early August have shown significant real-time skill since they began being issued in 1984. Our early April forecasts have also begun to show significant forecast skill in recent years. However, we have yet to demonstrate real-time forecast skill for our early December forecasts that have been issued for the last 20 years (1992-2011). Because of this lack of real-time forecast skill, we are suspending providing quantitative outlooks for specific numbers of named storms, hurricanes, hurricane days, etc. at this extended-range lead time. We will continue to investigate the potential for quantitative prediction at this

extended-range lead time and will re-institute quantitative outlooks if the potential for forecast skill looks good

We have previously developed three different early December seasonal forecast schemes for the following years' Atlantic basin seasonal hurricane activity.

1. Our initial 6-11 month early December seasonal hurricane forecast scheme (Scheme A) (Gray et al. 1992) demonstrated appreciable hindcast skill for the period from 1950-1990 (Table 1) but did not give skillful results when utilized for 10 real-time forecasts between 1992-2001. This was due to the discontinuation of the strong relationships we had earlier found between West African rainfall and the stratospheric quasi-biennial oscillation (QBO) with Atlantic basin major hurricane activity 6-11 months in the future. We did not expect these African rainfall and QBO predictive relationships that had worked so well during the 41-year period from 1950-1990 to stop working. We do not yet have a good explanation except that this scheme could not deal with conditions associated with a transition to a positive phase of the AMO in 1995. We discontinued this earlier 1 December forecast scheme and have developed two new 1 December forecast schemes (Schemes B and C) since that time.

Table 1: Cross-validated (jackknifed) hindcast variance explained of Gray et al. (1992) early December seasonal hurricane forecast model based upon the 1950-1990 development period.

Forecast Parameter	Variance Explained (r^2)
Named Storms (NS)	0.40
Named Storm Days (NSD)	0.49
Hurricanes (H)	0.47
Hurricane Days (HD)	0.51
Major Hurricanes (MH)	0.58
Major Hurricane Days (MHD)	0.52

2. Beginning with the 2002 December forecast for the 2003 season, we relied on a new early December forecast scheme (Scheme B) (Klotzbach and Gray 2004) which did not utilize West African rainfall and gave less weight to the QBO. This newer statistical scheme showed improved hindcast skill over the period from 1950-2001, correlating with observed NTC at 0.79 over the hindcast period. However, in ten years of real-time forecasts (from 2002-2011), the prediction scheme has only correlated with observations at 0.13. Figure 1 displays the hindcast versus observed NTC values from 1950-2001, along with real-time forecasts from 2002-2011. Note the remarkably good match from 1950-2001 and the degradation since that point.

Klotzbach and Gray (2004) Hindcasts/Forecasts

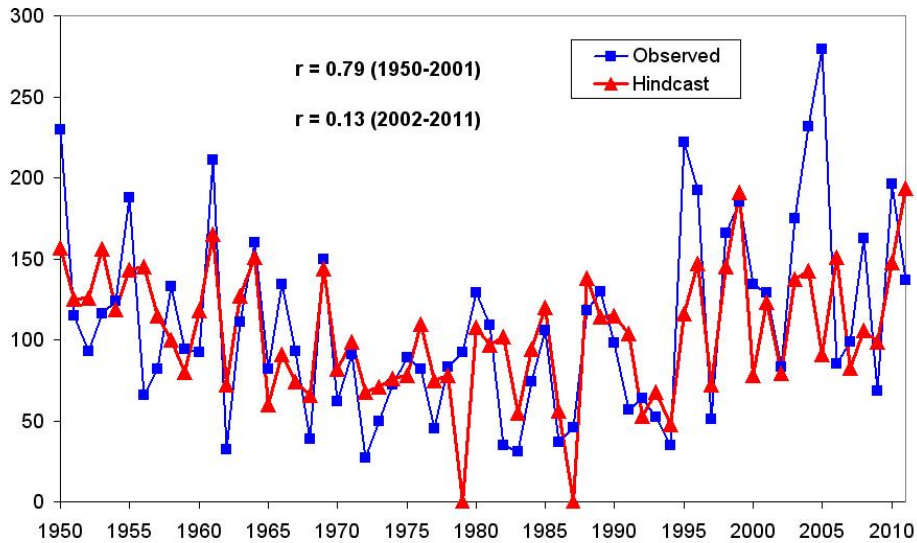


Figure 1: Hindcasts from 1950-2001 and real-time forecasts from 2002-2011 for the scheme documented in Klotzbach and Gray (2004). Note the degradation in forecast skill in recent years.

3. We spent much time in studying this extended-range forecast problem and developed a new statistical forecast methodology for our early December prediction in 2007 for the 2008 Atlantic hurricane season (Scheme C). This scheme showed similar hindcast skill to Scheme B while also using fewer predictors. For full details on this newer forecast methodology, please refer to Klotzbach (2008). Despite what appeared to be improvements in the forecast scheme, these forecasts have also failed to show real-time skill over the last four years (2008-2011). Figure 2 displays the hindcast skill of this forecast scheme from 1950-2007 along with real-time forecasts from 2008-2011.

Klotzbach (2008) Hindcast Skill

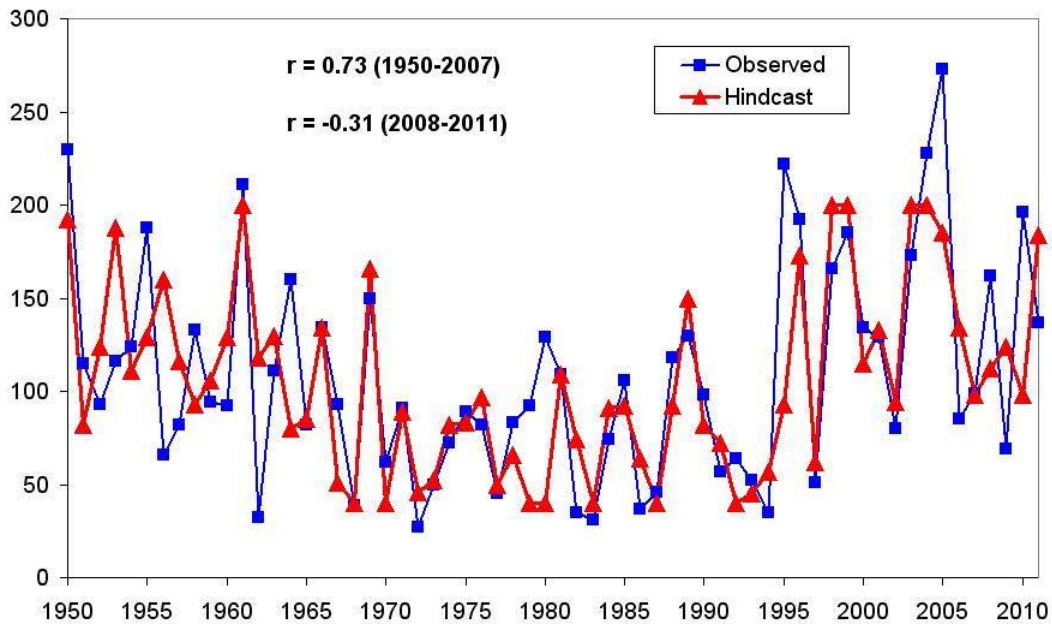


Figure 2: Hindcasts from 1950-2007 and real-time forecasts for 2008-2011 from the scheme documented in Klotzbach (2008). This model has not issued skillful forecasts in real-time mode from 2008-2011.

Figure 3 displays real-time forecast versus observed NTC from 1992-2011 for all of our early December extended-range lead time forecasts. We are very disappointed that all three of these early December forecasts, although showing very substantial hindcast skill, did not show real-time forecast skill. The variables that worked well in past years (or in hindcasts) did not continue to show strong relationships when applied to future years. This breakdown in climate prediction relationships is not specific to the prediction of Atlantic basin hurricanes from early December. Relationships between predictors and predictands which once seemed quite strong may fail to work in future years due to a phenomenon known as the 'siege of time'. It is the failure of these once-promising relationships which requires the forecaster to demand as much understanding of linkages between predictors and predictands as possible. Also, as the availability of prior years of past data becomes greater, statistical forecast schemes can be built on longer periods of hindcast data, which should hopefully reduce the likelihood of future-year degradation. We do not believe that human influences on climate are related to the breakdown of these prediction schemes.

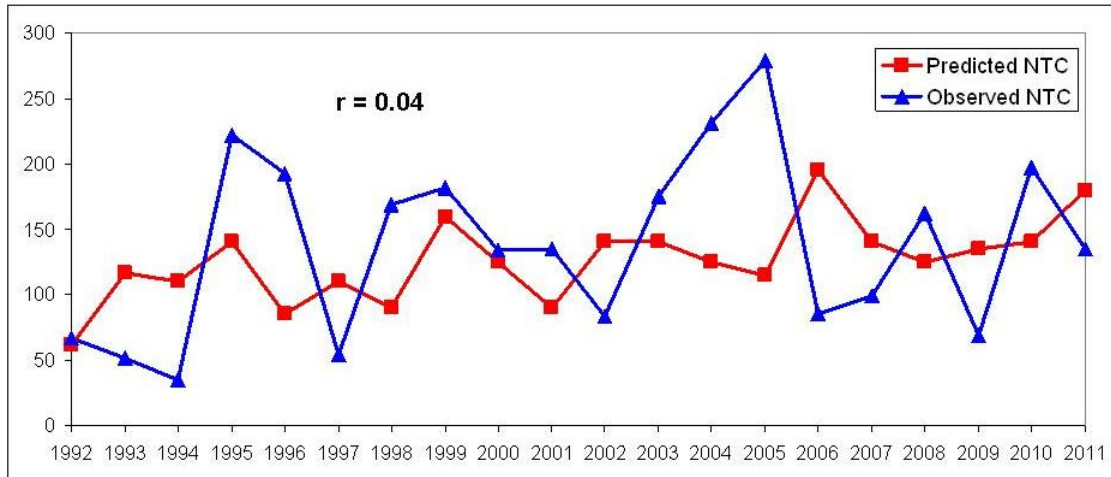


Figure 3: Observed versus predicted NTC from 20 years of real-time early December forecasts. The correlation between predicted and observed NTC is 0.04.

Because of this lack of real-time forecast skill, we will be issuing qualitative outlooks in early December for the foreseeable future. One of the primary impediments to successful forecasts at this lead time is likely due to the inability to predict ENSO through the springtime predictability barrier. We are conducting intensive research as to the possibility of issuing successful ENSO forecasts 6-11 months in the future in early December.

Over the next few pages, we discuss two large-scale physical features which we know are fundamental for how active the 2012 Atlantic hurricane season is likely to be.

3 The Atlantic Ocean Thermohaline Circulation (THC) or the Atlantic Multi-Decadal Oscillation (AMO)

THEORY OF THC (OR AMO) INFLUENCE ON ATLANTIC HURRICANE VARIABILITY

The longer-period SST changes which the Atlantic Ocean experiences are due primarily to variations in the strength of the southwest to northeast upper branch of the THC in the high latitude Atlantic. The THC (which is observed and modeled to vary considerably in strength on multi-decadal timescales) is strong when there is an above-average poleward advection of warm tropical waters to the high latitudes of the Atlantic. This poleward-moving water can then sink to deep levels if it has high enough salinity content. This sinking process has been termed North Atlantic Deep Water Formation (NADWF). The submerged deep water then moves southward at deep levels in the Atlantic into the Southern Hemisphere. The amount of North Atlantic water that sinks is roughly proportional to the waters' density which at high latitudes, where water temperatures are low, is primarily dependent on salinity content. The strong association

between North Atlantic SSTA and North Atlantic salinity is shown in Figure 4. High salinity implies higher rates of NADWF.

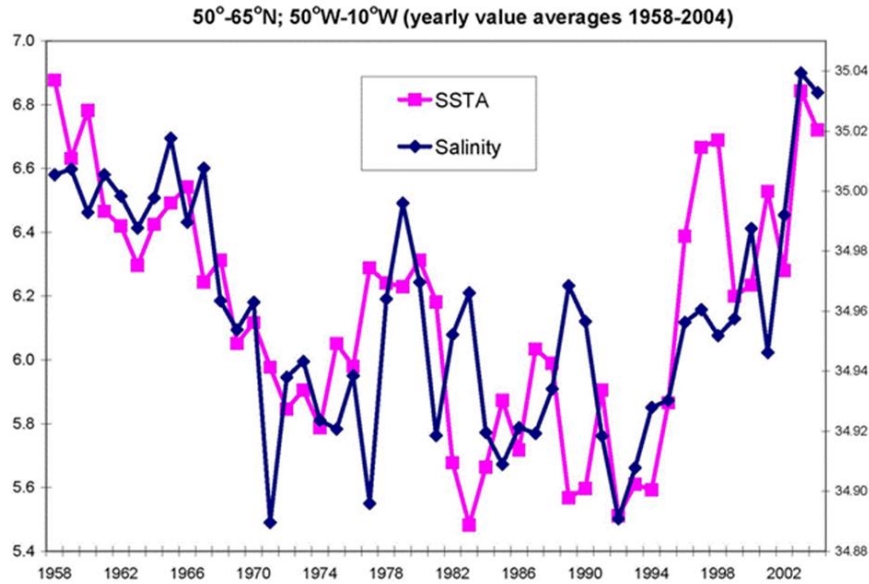


Figure 4: Illustration of the strong association of yearly average North Atlantic SSTA and North Atlantic salinity content between 1958 and 2004.

Through a progression of associations the strength of the NADWF is hypothesized to bring about alterations of the tropospheric vertical wind shear, trade wind strength, SSTs, middle-level water vapor, and other conditions in the Atlantic Main Development Region (MDR – 10-20°N; 20-70°W). Changes of SST in the MDR are a consequence of a combination of the THC's influences on a variety of other parameters in the MDR (Figure 5). A stronger than average THC causes more ocean sinking in area 1. This in turn reduces the strength of the Atlantic gyre. There is then a change in all of the other conditions shown in Figure 5 to bring about more favorable parameters in the MDR for TC formation and intensification. This figure illustrates how the changing rate of southward advection of cold water in the east Atlantic (2) brings about alterations of SLP (3), SST (4), and rainfall (5). These changes in turn lead to changes in trade wind strength (6) and 200 mb zonal wind (7). Increases in hurricane activity and especially major hurricane activity follow (8). It is also found that in periods with a strong THC, El Niño frequency and intensity is typically reduced (9) and tropical South Atlantic SSTs are decreased (10).

The influence of the warmer Atlantic SST is not primarily to enhance lapse rates and Cb convection in the MDR but to act as a net overall positive or negative influence on a combination of parameters that must all change in a positive way to enhance MDR TC activity. These features typically all go together as a package to either enhance or to inhibit TC formation and/or TC intensity change (Figure 6). The simple argument of

increasing or decreasing SST alone, without other important parameter changes is not typical of what we observe with TC activity variation in this region.

Higher rates of NADWF require stronger northward moving west Atlantic replacement water which is typically warmer, and if the stronger poleward flow is to continue, the replacement water must be of higher salinity content and consequently of higher density when such water cools toward freezing. Salinity dominates over water temperature when water temperatures are in the range of 0-7°C.

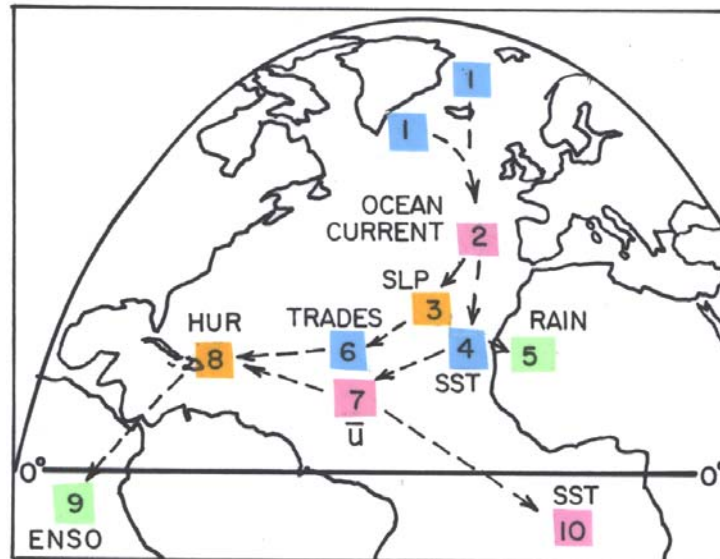


Figure 5: Idealized analysis of how changes in North Atlantic SST and salinity (area 1) lead to progressive ocean current, wind, pressure, SST, vertical shear or rain changes as portrayed in nine areas. It is this complete package of Atlantic/eastern Pacific meteorological parameter changes on a multi-decadal time scale which cause large changes in Atlantic major hurricanes on this time scale.

ATLANTIC OCEAN THC (or AMO) CHANGES

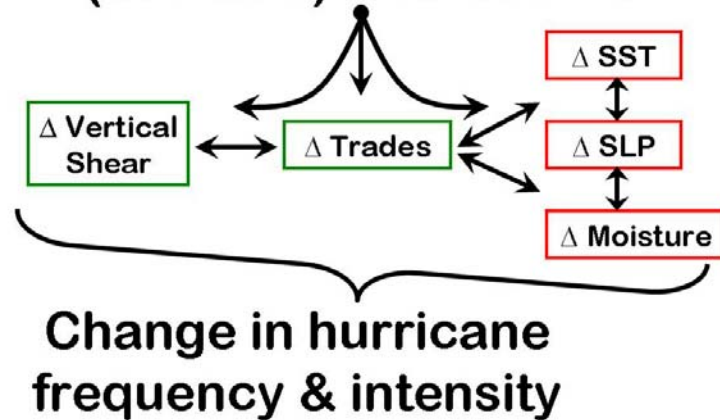


Figure 6: Idealized portrayal of how changes in the Atlantic THC bring about various parameter changes in the Atlantic’s MDR between 10-20°N; 20-70°W. Vertical shear, trade-wind strength, and SST are the key parameters which respond to the THC changes. Favorable SLPA and mid-level moisture changes occur in association with the shear, trade wind, and SST changes. It is the THC’s ability to affect a favorable alteration of a combination of these parameters within the MDR which leads to such a strong association between the strength of the THC and major hurricane frequency.

One of the primary physical drivers for active versus inactive Atlantic basin hurricane seasons is the strength of the THC or AMO (Goldenberg et al. 2001, Klotzbach and Gray 2008). A positive phase of the AMO (or strong phase of the THC) typically leads to 3-5 times more major Atlantic basin hurricane activity than does a negative phase. The typical period of the THC is about 60 years, with the period length varying between as short as 40-50 years and as long as 70-80 years. This means that we typically have 25-35 years of above-average Atlantic basin major TC activity and similar length periods with considerably reduced amounts of major TC activity. Strong THC or positive AMO conditions are characterized by positive SSTA and salinity content in the North Atlantic, increased rainfall in the Sahel region of Africa, warmer tropical Atlantic SST, reduced sea level pressure in the tropical Atlantic, reduced ENSO frequency and a wide variety of other physical processes. It is not specifically one parameter, such as tropical Atlantic SST, which is dominant but rather the combination of 4-5 parameters which all change sign together in a manner acting to either enhance or reduce Atlantic major hurricane activity.

While the THC typically remains in an above-average or in a below-average stage for periods of 25-35 years, there can be monthly, seasonal or longer breaks up to a year or two within these longer periods when the AMO (or THC) conditions of features such as SST, salinity, pressure, wind, and moisture become substantially weaker in positive phases or stronger during negative phases. During these periods where the multi-decadal signal is interrupted, we sometimes observe below-average TC activity during a positive

phase (e.g., 1962 and 1968) or above-average TC activity during a negative phase (e.g., 1988 and 1989).

We believe that the positive AMO (and strong THC) that has typically been present since 1995 experienced a modest temporary weakening during 2011. This helped cause the Atlantic gyre to become stronger, the eastern Atlantic SST to become cooler, and Atlantic tropospheric westerly vertical wind shear to increase across the Atlantic subtropics (20°N-30°N). This unexpected weakening of the AMO/THC is one of the reasons why we likely over-estimated major hurricane activity during 2011.

4 ENSO

We currently have a weak/moderate La Niña event in place over the tropical Pacific. Following a rapid transition from a strong La Niña to neutral conditions during this past spring through summer, cool ENSO conditions re-established themselves during the fall. Observed sea surface temperatures anomalies in the eastern and central Pacific are approximately 0.5 – 1.0°C below the long-period average while the September-October-averaged Multivariate Enso Index (MEI) (Wolter and Timlin 1998) is currently 1.0 standard deviations below average. We find that the MEI is a more robust index of ENSO conditions than simply using a particular SST index, as the MEI also takes into account sea level pressure, zonal and meridional winds and cloudiness. By doing this, it provides a more exact measure of what is actually going on in the atmosphere/ocean system. The MEI is defined by a bi-monthly average (e.g., August-September) and extends back to 1950. While the September-October-averaged MEI is well below-average, it is about one standard deviation higher than was observed in September-October of 2010. Current values of the MEI are similar to those observed in September-October of 1999 and 2008, respectively.

One of the important questions for the upcoming hurricane season is whether El Niño will re-develop for the 2012 hurricane season. Table 2 displays years since 1950 with similar September-October MEI values to 2011 (from 0.5 -1.5 standard deviations below normal). Also displayed are the following year's August-September MEI values. Of the fourteen years with similar MEI values to late 2011, five (36%) experienced El Niño conditions (defined as an August-September MEI greater than 0.5 standard deviations above normal) the following year. In addition, we have now gone since 2009 without an El Niño. Typically, warm ENSO events occur about 3-7 years.

Another aspect to this upcoming hurricane season is that we will likely have a multi-winter La Niña event observed during the winters of 2010/2011 and 2011/2012. Most dynamical and statistical models indicate the continuation of cool ENSO conditions during the next few months. Assuming that these models are correct (and ENSO models typically have good skill during the winter months), we next examine multi-year La Niña events (defined as the Oceanic Nino Index (ONI) being less than -0.5 standard deviations for five overlapping three-month periods during the October-March period). Table 3 displays the December-February-averaged ONI along with the August-October ONI

observed the following year. Four of the eight August-October periods following a multi-year La Niña winter had El Niño conditions.

Given this analysis, there is significant uncertainty in exactly what ENSO conditions will look like next year. Most statistical and dynamical forecast models indicate that La Niña will persist through the winter (Figure 7), with some moderation during the upcoming spring in the Nino 3.4 region (5°S-5°N, 120°-170°W). The ECMWF model appears to be somewhat more aggressive at warming during the spring months than several of the other forecasts, with several ensemble members indicating SSTs exceeding 0.5°C by May for the Nino 3.4 region (Figure 8), and the potential for SSTs exceeding 1.0°C by May in the Nino 3 region (5°S-5°N, 90°-150°W) (Figure 9). In general, this model has the highest levels of skill at predicting ENSO events, and consequently, there appears to be some likelihood that an El Niño will develop next year. We will be closely monitoring ENSO conditions over the next few months and will have more to say with our early April update.

Table 2: Years with September-October MEI values between -0.5 and -1.5 standard deviations, and the following year's August-September MEI values. Five of the fourteen years had El Niño develop by the later part of the following summer.

Year	September-October MEI	Following Year's August-September MEI
1954	-1.4	-1.8
1956	-1.5	1.2
1961	-0.5	-0.6
1962	-0.7	0.8
1964	-1.2	1.4
1967	-0.7	0.2
1970	-1.1	-1.5
1971	-1.4	1.5
1974	-1.0	-1.9
1988	-1.4	-0.3
1998	-0.9	-1.0
1999	-1.0	-0.2
2007	-1.1	-0.7
2008	-0.8	0.8
Average	-1.0	-0.1
2011	-1.0	

Table 3: December-February-averaged ONI for consecutive La Niña winters and observed August-October-averaged ONI for the following summer/fall. ONI values are in parentheses. The December-February averaged ONI for 2011/2012 is estimated.

Multi-Year La Niña Events (ONI in parentheses)	Following August-October (ONI in parentheses)
1950 (-1.7) – 1951 (-1.0)	1951 (0.7)
1955 (-1.0) – 1956 (-1.3)	1956 (-0.8)
1956 (-1.3) – 1957 (-0.5)	1957 (0.9)
1971 (-1.3) – 1972 (-0.7)	1972 (1.5)
1974 (-1.9) – 1975 (-0.6)	1975 (-1.5)
1975 (-0.6) – 1976 (-1.6)	1976 (0.5)
1999 (-1.4) – 2000 (-1.6)	2000 (-0.4)
2000 (-1.6) – 2001 (-0.6)	2001 (0.2)
1st Year Average (-1.4) – 2nd Year Average (-0.9)	+0.1
2011 (-1.3) – 2012 (~-0.9)	

Model Predictions of ENSO from Nov 2011

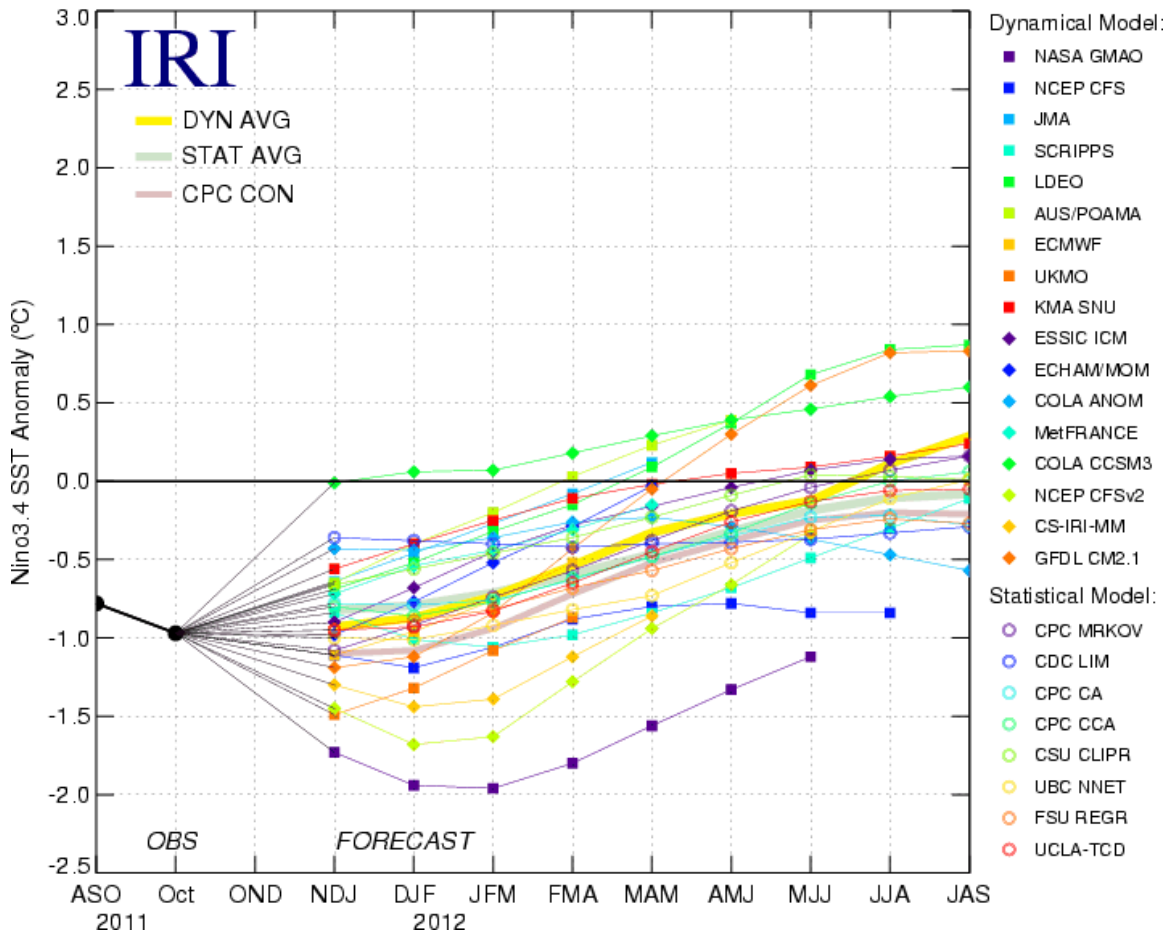


Figure 7: ENSO forecasts from various statistical and dynamical models. Figure courtesy of the International Research Institute (IRI).

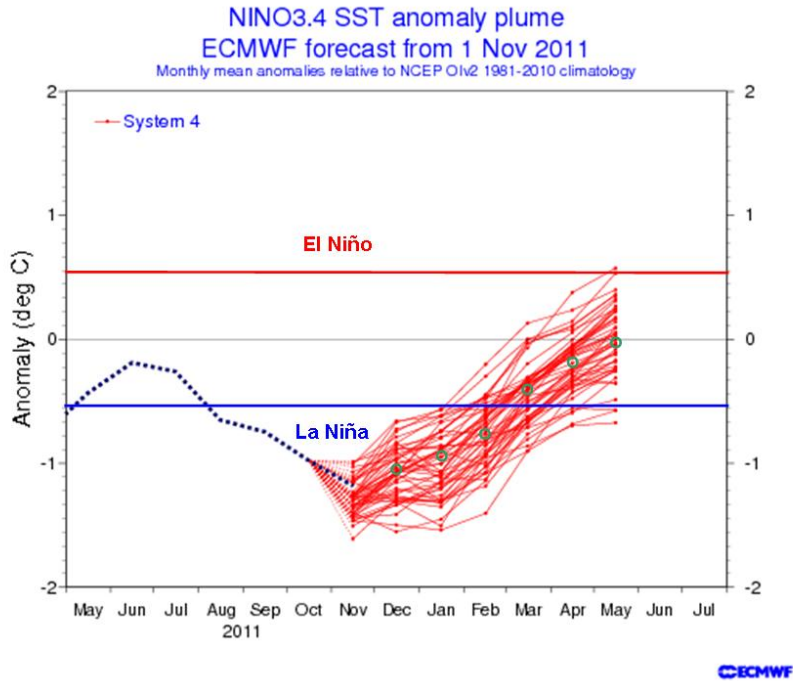


Figure 8: Scatterplot of ECMWF system 4 ensemble members for the Nino 3.4 region. Note that several members approach the El Niño threshold by May. The green circle indicates the approximate midpoint of ensemble members.

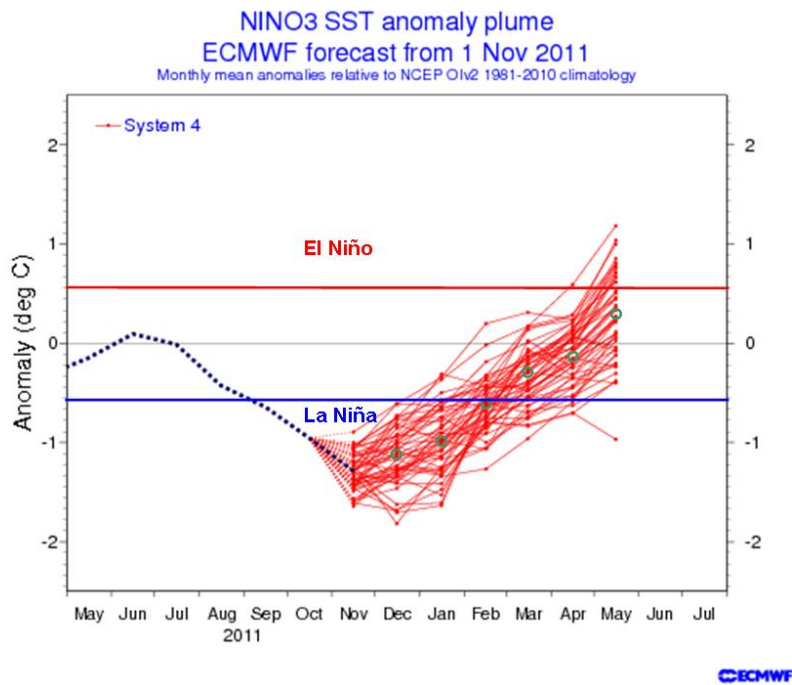


Figure 9: Scatterplot of ECMWF system 4 ensemble members for the Nino 3 region. Approximately 1/3 of ensemble members approach or exceed the El Niño threshold by May. The green circle indicates the approximate midpoint of ensemble members.

5 Atlantic Basin Sea Surface Temperatures

Tropical Atlantic SSTs have cooled considerably since 2010; however, they remain at above-average values. Figure 10 displays currently-observed global SST anomalies. Warm anomalies persist across the tropical Atlantic and far North Atlantic, indicative of an active phase of the AMO and a strong phase of the THC.

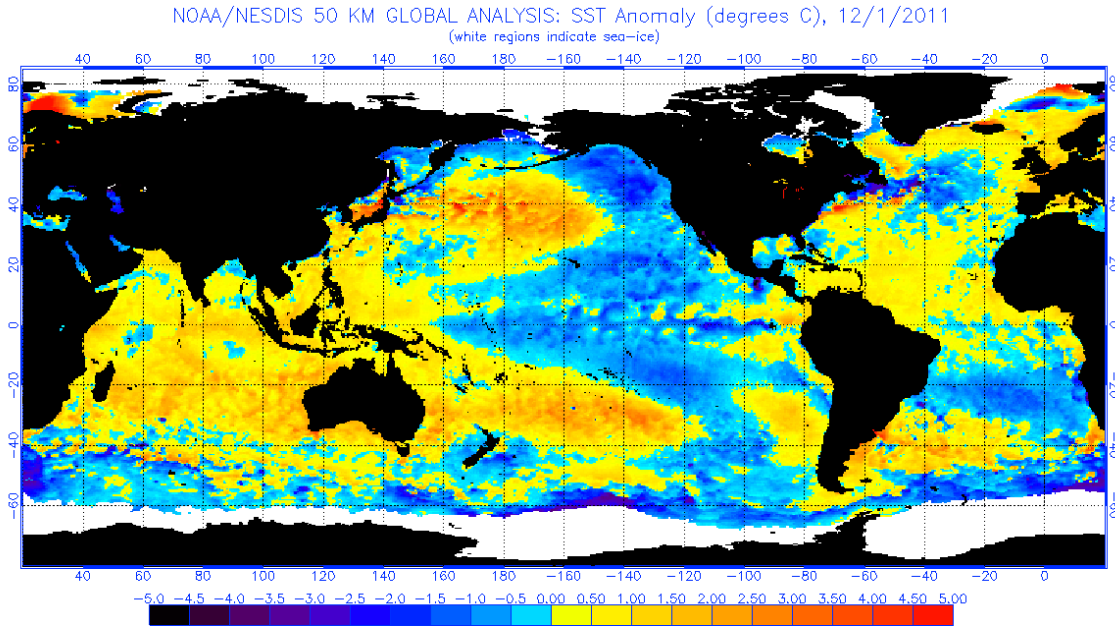


Figure 10: Currently-observed global SST anomalies.

Two factors that need to be considered during this upcoming winter are a typical tropical Atlantic SST response to a La Niña event, along with trade wind strength across the tropical and subtropical Atlantic. When La Niña occurs, the Walker Circulation is enhanced, which favors increased rainfall and cloudiness and concomitantly cools the tropical Atlantic. Stronger-than-normal trade winds (similar to what was observed in February-March of 2011) can also act to cool the tropical Atlantic, through enhanced evaporation, upwelling and oceanic flow from the north. Both of these conditions will be closely monitored and discussed in detail with our early April outlook.

6 Qualitative 2012 Hurricane Outlook Summary

Two of the major influences that need to be monitored during the winter of 2011/2012 are the state of ENSO and the strength of the AMO (THC). As mentioned in our discussion, we believe that we remain in an active era for Atlantic basin tropical cyclones, and consequently, if El Niño does not develop, an active season is likely. However, given our current statistical analysis, it appears that there is a moderate chance (30-50%) that El Niño will develop for the 2012 Atlantic basin hurricane season. By early April of next year, we should have a better idea of the likelihood of ENSO

developing. Both dynamical and statistical ENSO forecast models show significantly improved skill for an August-October forecast by early spring.

The following calculations assume that we remain in an active phase of the THC (positive phase of the AMO) for the 2012 Atlantic hurricane season. Table 4 displays the median season experienced during an active phase of the THC (1950-1969, 1995-2011). Also included are the median active THC years when an El Niño takes place, along with the median for all other years where either neutral or La Niña conditions are present. For this analysis, we define El Niño to be when the August-October Niño 3.4 index is greater than 0.5°C.

Table 4: Active THC median tropical cyclone values, active THC El Niño tropical cyclone values and all other active THC years.

Forecast Parameter	Active THC (All Years)	Active THC (El Niño)	Active THC (La Niña or Neutral ENSO)
Named Storms (NS)	12.0	9.5	12.0
Named Storm Days (NSD)	64.0	52.4	70.8
Hurricanes (H)	7.0	4.5	7.0
Hurricane Days (HD)	31.5	24.3	32.8
Major Hurricanes (MH)	3.0	2.0	3.0
Major Hurricane Days (MHD)	7.5	6.6	9.5
Accumulated Cyclone Energy (ACE)	121	84	125
Net Tropical Cyclone Activity (NTC)	135	86	140

For comparison, we now provide a similar analysis for the inactive phase of the THC (1970-1994). Table 5 displays the median for all inactive THC years, inactive THC years when an El Niño takes place, and the median for all other years where either neutral or La Niña conditions are present. Note how much lower the statistics are for all three columns, especially for El Niño years. An additional interesting fact is that the median El Niño year in an active THC phase is comparable to a non-El Niño year in an inactive THC phase.

Table 5: The inactive THC median tropical cyclone values, inactive THC El Niño tropical cyclone values and all other inactive THC years.

Forecast Parameter	Inactive THC (All Years)	Inactive THC (El Niño)	Inactive THC (La Niña or Neutral ENSO)
Named Storms (NS)	9.0	7.0	11.0
Named Storm Days (NSD)	40.5	28.8	46.1
Hurricanes (H)	5.0	3.0	5.0
Hurricane Days (HD)	14.3	7.3	19.4
Major Hurricanes (MH)	1.0	1.0	2.0
Major Hurricane Days (MHD)	1.0	0.5	2.9
Accumulated Cyclone Energy (ACE)	68	36	80
Net Tropical Cyclone Activity (NTC)	80	38	87

At this extended lead time when ENSO forecasts have little skill, we expect to see an active season (in keeping with the median of the right-hand column in Table 4) unless an El Niño develops. In that case, we would expect to see activity more in line with the third column of Table 4. At this point, we do not expect the THC to weaken substantially for the 2012 Atlantic hurricane season, but if that were the case, we would expect activity more in line with the median values listed in Table 5.

With our forecast issued in early April, we will also provide landfall probabilities for the United States coastline and the Caribbean. On a statistical basis, more active tropical cyclone seasons tend to have more landfalling hurricanes. Lastly, we reiterate the outlook discussed in our abstract as our best estimate for the 2012 Atlantic hurricane season:

-
1. THC circulation becomes unusually strong in 2012 and no El Niño event occurs (resulting in a seasonal average net tropical cyclone (NTC) activity of ~ 180) – **15% chance**.
 2. THC continues in the above-average condition it has been in since 1995 and no El Niño develops (NTC ~ 140) – **45% chance**.
 3. THC continues in above-average condition it has been in since 1995 with the development of a significant El Niño (NTC ~ 75) – **30% chance**.
 4. THC becomes weaker and there is the development of a significant El Niño (NTC ~ 40) – **10% chance**.
-

Typically, seasons with the above-listed NTC values have TC activity as follows:

180 NTC – 14-17 named storms, 9-11 hurricanes, 4-5 major hurricanes
140 NTC – 12-15 named storms, 7-9 hurricanes, 3-4 major hurricanes
75 NTC – 8-11 named storms, 3-5 hurricanes, 1-2 major hurricanes
40 NTC – 5-7 named storms, 2-3 hurricanes, 0-1 major hurricanes

7 Have Atmospheric CO₂ Increases Been Responsible for the Recent Large Upswing (since 1995) in Atlantic Basin Major Hurricanes?

We strongly believe that the increases in atmospheric CO₂ since the start of the 20th century have had little or no significant effect on Atlantic basin or global TC activity as extensively discussed in our many previous forecast write-ups and recently in [Gray \(2011\)](#). Global tropical cyclone activity has shown no significant trend over the past thirty years.

8 Forthcoming Updated Forecasts of 2012 Hurricane Activity

We will be issuing seasonal updates of our 2012 Atlantic basin hurricane forecasts on **Wednesday April 4, Friday 1 June, and Friday 3 August**. We will also be issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August-October. A verification and discussion of all 2012 forecasts will be issued in late November 2012. All of these forecasts will be available on the web at: <http://hurricane.atmos.colostate.edu/Forecasts>.

9 Acknowledgments

Besides the individuals named on page 3, there have been a number of other meteorologists that have furnished us with data and given valuable assessments of the current state of global atmospheric and oceanic conditions. These include Brian McNoldy, Art Douglas, Ray Zehr, Mark DeMaria, Todd Kimberlain, Paul Roundy and Amato Evan. In addition, Barbara Brumit and Amie Hedstrom have provided excellent manuscript, graphical and data analysis and assistance over a number of years. We have profited over the years from many in-depth discussions with most of the current and past NHC hurricane forecasters. The second author would further like to acknowledge the encouragement he has received for this type of forecasting research application from Neil Frank, Robert Sheets, Robert Burpee, Jerry Jarrell, and Max Mayfield, former directors of the National Hurricane Center (NHC) and the current director, Bill Read.

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11 Verification of Previous Forecasts

Table 6: Summary verification of the authors' five previous years of seasonal forecasts for Atlantic TC activity between 2007-2011.

2007	8 Dec. 2006	Update 3 April	Update 31 May	Update 3 August	Obs.
Hurricanes	7	9	9	8	6
Named Storms	14	17	17	15	15
Hurricane Days	35	40	40	35	11.25
Named Storm Days	70	85	85	75	34.50
Major Hurricanes	3	5	5	4	2
Major Hurricane Days	8	11	11	10	5.75
Net Tropical Cyclone Activity	140	185	185	160	97
2008	7 Dec. 2007	Update 9 April	Update 3 June	Update 5 August	Obs.
Hurricanes	7	8	8	9	8
Named Storms	13	15	15	17	16
Hurricane Days	30	40	40	45	29.50
Named Storm Days	60	80	80	90	84.75
Major Hurricanes	3	4	4	5	5
Major Hurricane Days	6	9	9	11	8.50
Accumulated Cyclone Energy	115	150	150	175	146
Net Tropical Cyclone Activity	125	160	160	190	164
2009	10 Dec. 2008	Update 9 April	Update 2 June	Update 4 August	Obs.
Hurricanes	7	6	5	4	3
Named Storms	14	12	11	10	9
Hurricane Days	30	25	20	18	11.25
Named Storm Days	70	55	50	45	27.25
Major Hurricanes	3	2	2	2	2
Major Hurricane Days	7	5	4	4	3.25
Accumulated Cyclone Energy	125	100	85	80	50
Net Tropical Cyclone Activity	135	105	90	85	66
2010	9 Dec. 2009	Update 7 April	Update 2 June	Update 4 August	Obs.
Hurricanes	6-8	8	10	10	12
Named Storms	11-16	15	18	18	19
Hurricane Days	24-39	35	40	40	37.50
Named Storm Days	51-75	75	90	90	88.25
Major Hurricanes	3-5	4	5	5	5
Major Hurricane Days	6-12	10	13	13	11
Accumulated Cyclone Energy	100-162	150	185	185	163
Net Tropical Cyclone Activity	108-172	160	195	195	195
2011	8 Dec. 2010	Update 6 April	Update 1 June	Update 3 August	Obs.
Hurricanes	9	9	9	9	7
Named Storms	17	16	16	16	19
Hurricane Days	40	35	35	35	25
Named Storm Days	85	80	80	80	90.50
Major Hurricanes	5	5	5	5	3
Major Hurricane Days	10	10	10	10	4.50
Accumulated Cyclone Energy	165	160	160	160	125
Net Tropical Cyclone Activity	180	175	175	175	137